The Effects of Poor Internal Quality on Customer Satisfaction

Alexandr M. Sokolov, Ph.D., Steven Picklesimon, M.Sc., Duaa Nawafleh, M.Sc. and Niamat Ullah Ibne Hossain, Ph.D.
Engineering Management Program
Arkansas State University
State University, AR 72467, USA
asokolov@astate.edu, steven.picklesi@smail.astate.edu, dnawafleh@astate.edu, nibnehossain@astate.edu

Abstract

Current advances in manufacturing technology have made the automotive market much more competitive. Customers are seeking the best products at the lowest possible cost. To maintain the best possible working relationship, it is every supplier's responsibility to ship products that meet the requirements and are on time. This paper will focus on how internal scrap costs can directly correlate to externally received customer complaints. Quality scrap is a large driver in cost, shipment timing, and customer satisfaction. Every part made internally that is defective is at risk of being shipped to the customer. The higher the scrap cost the more likely a supplier is to ship a bad part. This will cause customers to lose faith in the supplier's ability to produce a quality part and may lead to the customer seeking a different supplier in the future. To verify this relationship, a study was done on 4 different business groups in a company, comparing the percentage of internal scrap vs. overall sales per month and the complaints received. The results show that there is a relationship between internal scrap cost and customer complaints, but there are other factors that can contribute.

Keywords
Cost of quality (COQ), Customer Satisfaction, Scrap

1. Introduction
Some may ask, "What is Cost of Quality (COQ)?" American Society of Quality (ASQ) defines the COQ as "a methodology that allows an organization to determine the extent to which its resources are used for activities that prevent poor quality, that appraise the quality of the organization's products or services, and that result from internal and external failures". While this is a sufficient definition, COQ is much more complex. Quality-One International defines COQ as "all costs associated with the quality of a product from preventive costs intended to reduce or eliminate failures, cost of process controls to maintain quality levels and the costs related to failures both internal and external." These costs are used by companies to evaluate the need for more resources (equipment, manpower, etc.).

This study focuses on the cost of poor quality associated with internal defect costs compared to the number of customer complaints received during 3 a year span. The crucial piece of this definition is the result of internal and external failures. Every day at automotive manufacturing facilities millions of parts are being produced. Most of these parts are of the utmost quality, but others do not meet the desired specifications and are considered scrap. Each piece of scrap strikes a company's profit margin as well as poses a potential risk of shipping non-conforming parts to all customers. Internal and external failures are the most significant contributors of COPQ, as they can range between 20% and 100% and comprise the total costs of goods produced (Galli, B. J. 2021). The particular company studied sets a target of scrap cost as a percentage of sales. As the percentage of scrap costs rises, the number of complaints also rises. While this indicates there is a correlation, there are other participating elements to be explored.

1.1 Background
Making a quality component is vital to customer satisfaction. Each company in the field must maintain product quality, deliver on time and at a competitive price to achieve customer satisfaction (Misztal, A., Grecu, I., & Belu, N. 2016). Companies have increasingly focused their attention on quality costs because related activities use substantial

resources, which directly affect business performance. Shipping a non-conforming part to the customer can quickly make a customer lose trust in a company's ability to produce parts that will guarantee the satisfaction of the consumer. Producing non-conforming parts also has a large impact on a company's profit margin.

Usually, quality costs are understood as the total amount of conformity and unconformity quality costs, when conformity costs are attributed to prevention and assessment quality costs in order to avoid unconformity, and unconformity quality costs are attributed to the internal and external non-conformance quality costs (e.g.: product's return or re-production) (Daunoriene, A., & Katiliute, E. 2016). Shipping non-conforming parts can cost anywhere from a couple of hundred dollars up into the millions if the issue turns into a vehicle recall. This also results in a formal notice from the customer that will require a thorough investigation, taking both valuable time and potential investment. These investigations must be documented in the customer directed format (8D, 5 Why, Fault Tree Analysis etc.) and then must be submitted and approved by the customer. Repeat incidents can lead to a loss of business.

There is also the internal cost incurred by scrapping non-conforming parts that are caught before leaving the facility. Internal failure costs are those costs associated with product failure before its delivery to the external customer. They include the net cost of scrap, spoilage, rework, material wastage, labor wastage, overheads associated with production, failure analysis, supplier rework, scrap, re-inspection, retest, downtime due to quality problem, opportunity cost, or other product downgrades (Mahmood, S., Ahmed, S. M., Panthi, K., & Kureshi, N. I. 2014). A study done by Abbas, S. N., Ahmed, J., Salman, M., &Ashraf, S. R. (2015) found that the cost of good quality is 22 ~ 50 times lower than cost of poor quality.

2. Related Literature

Quality is defined in many ways. The definition most relevant to this paper is given by Juran (2017) as "Quality means freedom from deficiencies—freedom from errors that require rework." (Rust et al, 1995) have identified quality as the most important and complex element for attraction of customers and business growth. From the popular cult novel by Pirsig (1974, pp 260) which says, "Even though quality cannot be defined, you know what Quality is!" to the modern definition describing the inverse relation between quality and variance, a wide breadth of research has advanced the understanding of product quality Montgomery (2013). Open-ended statements like the one made by Reeves and Bednar (1994), "Different definitions of quality are appropriate under different circumstances," are, in this paper, regarded as insufficient. Instead, a definition that may be applied to objectively quantify quality as it pertains to *any* product is needed. Keeping this in mind, Douglas C. Montgomery, in his book "Introduction to Statistical Quality Control," adopted Garvin's sub-categorization of quality into eight stages, termed as "The Eight Dimensions of Quality" (Garvin, 1984; Montgomery, 2013).

Due to widely published success of methods such as Six Sigma and TQM, much research has been conducted to further understanding and facilitate implementation. (Zu et al., 2010) examined the influence, based on the competing values framework, of different organizational culture types on TQM and Six Sigma implementation success. Through a survey of industry experts, strong links were identified between facets of the Group, Developmental, and Rational cultures and TQM and Six Sigma implementation. Another survey and analysis was conducted by (Drohomeretski et al., 2014) comparing Six Sigma, Lean and LSS concluding that LSS fusion offers the potential for superior quality and greater reliability. In an auto-industry case study for example, (Gijo & Scaria, 2014) applied Six Sigma DMAIC to achieve a 4.6% increase in first pass yield. (Albliwi et al., 2014) Investigated factors leading to failure of Lean, Six Sigma, and LSS initiatives. In this 56-paper literature review covering work from 1995 to 2013, 34 critical factors such as lack of management support and lack of resources were identified. To address the needs of technology intensive manufacturing firms, (Colledani et al., 2014) suggested a post-Six Sigma paradigm is needed. In this paper, a study of real industry examples is made concluding implementation of new advanced technologies is needed to integrate management of production, logistics, quality, and maintenance functions. In the case study of a yogurt production process in Iran, Six Sigma DMAIC was applied to improve quality by defining and controlling optimal product pH levels (Hakimi et al., 2018). Another case study in the iron casting industry showed that Six Sigma DMAIC could be used to analyze quality issues. The data from this analysis were applied to a predictive analytics model that, when implemented, yielded a 99 per cent reduction in rejection rate and 19.78 per cent increase in on-time delivery (Mishra & Rane, 2019).

It is apparent from the thread of extant literature that although there is a plethora of techniques adopted to enhance the quality aspects of organizations by different means, there are few research that have performed an analysis on how to reduce internal scrap costs in order to enhance customer satisfaction. To fill this void, we assess how internal scrap costs can directly correlate to externally received customer complaints and ultimately enhance the quality standards of the corresponding organization/industry.

3. Methods of improving products and Achieving Customer Needs

3.1 Lean Manufacturing Principle

The automotive sector shows an intense worldwide competition along with the technological advancements resulting in unlimited business opportunities for the automotive companies (Saad, N. H., Khalid, Q. M., Halim, N. H. A., & Khusaini, N. S. 2020). With the automotive industry being on the cutting edge of new technologies companies are looking for ways to improve productivity and decrease defects. Dhiravidamani, P. & Ramkumar, A. & S.G., Ponnambalam & Subramanian, Nachiappan. (2017) states that in the present competitive and demanding business markets, manufacturing industries need to improve their strength and must concentrate on their process flows by assigning the task resources carefully to improve productivity. This had led to a focus on the principle of lean manufacturing, also known as Just in Time.

Lean manufacturing or lean production is a systematic method for the elimination of waste within a manufacturing process. (Shah and Ward 2003). Toyota's effort to continuously improve their production system during the last 40-plus years, along with diffusion of their improved production system to other Japanese companies and a dedicated effort to pursue perfection by participating Japanese companies, has resulted in the efficient, integrated, manufacturing system known as Just-In-Time (JIT) manufacturing (White, R. E., Pearson, J. N., & Wilson, J. R. 1999). In today's world, the industrial scene has faced higher challenges because of the rise in international competition; lean manufacturing (LM) has been taking part in a crucial role to boost companies' performance, not solely performance at the operations levels however additionally at the business level (Singh, J., & Singh, H. 2020). To cut down on waste companies only keep on hand what is needed. This includes supplied parts, in-process parts, and completed finished goods ready to ship to the customer. By doing this it eliminates the need for unnecessary space that all the additional inventory would normally take up. Most production runs are based solely on what the customer orders. By doing this also helps eliminate the risk of having a large stock of non-conforming parts. This also can pose a unique risk. Usually, parts being produced are being processed to ship either the same day or the next day. If there is a quality incident that goes unnoticed for a short amount of time there is a much higher risk that it will ship to the customer before being discovered, resulting in a potential complaint.

3.1 Quality Control Principle

Companies using a lean manufacturing system must put a large emphasis on quality control. This control is ensured by a company having a robust quality management system (QMS). ASQ defines a QMS as a formalized system that documents processes, procedures, and responsibilities for achieving quality policies and objectives. This is a comprehensive system that outlines how a company achieves and maintains top-tier quality. ISO9000 standards provide a framework for quality management in organization (Papadimitriou, A., & Westerheijden, D. F. 2010). ISO9000 can be implemented in any type of industry from simple manufacturing to aerospace manufacturing. Based on ISO 9000, IATF 16949 is an international fundamental Quality Management System (QMS) specification for the automotive industry (C. P. Kartha 2004). IATF 16949 standards is a Quality Management System that provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the supply chain (Saad, N. H., Qhairunisha, M. K., Nurul Hayati, A. H., & Khusaini, N. S. 2020).

Most automotive customers now require that their suppliers be IATF 16949 certified. This requires a certification body to come and do a yearly surveillance audit as we as recertification audits every 3 years. During these audits, flaws are identified in how a company implements, monitors, and improves its QMS regularly. These are then documented in corrective actions that a company must countermeasure to be in compliance and create a more robust QMS. The main focus of IATF is to reduce risk. This is risk in the supply chain, internal risk, the risk to the customers, etc. Two documents generally come to mind when discussing mitigating internal risk, Control Plan and Process Failure Mode and Effects Analysis (PFMEA). Quality-One International defines a control plan as "a document that describes the actions (measurements, inspections, quality checks or monitoring of process parameters) required at each phase of a process to assure the process outputs will conform to pre-determined requirements." Quality-One International also defines a PFMEA as "a methodical approach used for identifying risks on process changes. The Process FMEA initially identifies process functions, failure modes their effects on the process." Both documents are living documents that are updated for any changes or issues that arise. Data is gathered continuously and is compared to set targets to check the effectiveness of the controls. If gaps are identified, then investigations are done, and solutions are implemented. This could include updating work instructions, implementing new technology, updating the control plan and PFMEA, etc.

4. Data Collection and Processing

The data collected for this study is from a company that is IATF 16949 certified and uses a lean manufacturing system. A 3-year period was looked at from March 2018 to March 2021. The company used for this study has multiple different distinct business units that produce a multitude of parts. Each business unit produces parts for different industries such as Aerospace, Automotive, Medical, etc. that are unique to that unit. The production techniques used are also unique to each business unit, they range from Injection Molding, High-Speed Assembly, Electric Circuit Printing, Lamination, etc. This can create a challenge when trying to create a QMS that works for all units involved especially since each industry has its own specific requirements. The scrap cost in US dollars is collected for every month and are compared to total sales for the given month for each business unit. The scrap cost for each month is then converted to a ratio of the percentage of sales. If the scrap dollars were used it could potentially skew the data due to the fluctuation in sales. Months with higher sales leads to an increase in production which in turn would potentially increase the scrap costs incurred during that month. Expressing the data as a percentage of sales helps normalize the data. The scrap percentage is then compared to the number of customer complaints received during the same period. The goal is to show a correlation between the scrap cost and the number of complaints received. Figure 1 below shows the 3-year trend for scrap percentage versus the number of complaints received per month for 4 different business units.

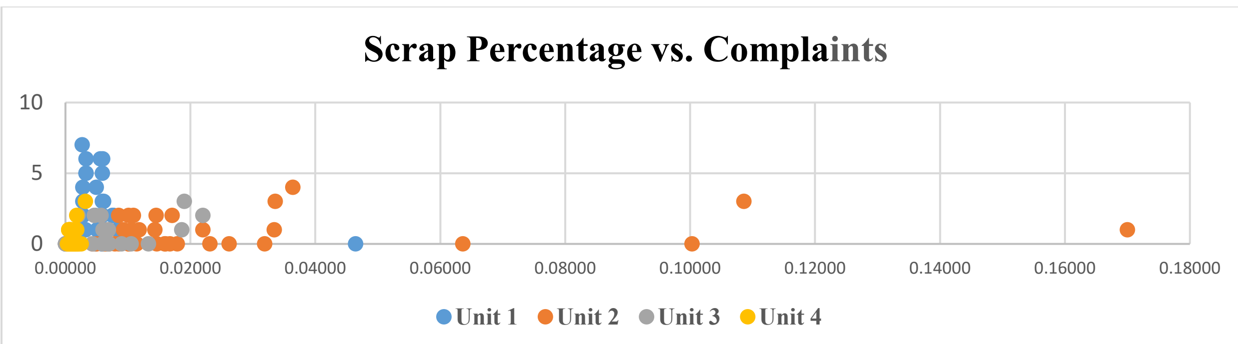

Figure 1. Scatterplot of Scrap Percentage vs. Customer Complaints

As seen in the scatterplot most of the points are clustered between the zero percent and two percent mark. There are a few outliers from business unit two. These outliers can be attributed to the transferring of the business from one location to another. During this transfer, there was a steep learning curve that caused scrap rates to be excessive, but there were special inspections in place that further prevented non-conforming parts from being shipped. There is also a distinguishable difference in the amount of scrap produced for each business unit. This is due to the complexity of the parts produced and the technologies used. While the scatter plot does a great job of visually representing the data it does not really indicate whether there is a correlation or not. To determine this a more thorough statistical analysis is need.

5. Results and Discussion

5.1 Statistical Analysis

The goal of this study was to see if there was a definitive correlation between scrap percentage and complaints received. Two statistical tests were performed, a simple correlation study and linear regression model.

5.1.1 Correlation

A simple correlation was performed to test if there was a direct correlation between the two variables. This was done in excel by simply comparing the two values for all 4 business units. This produces the Pearson Correlation Coefficient (r-value). This r-value range from -1 to 1. If the value is a negative r-value that means, there is a negative correlation or that as one value increases or decreases the other value does the opposite. A positive r-value indicates a positive correlation or that as one value increases or decreases the other value does the same. The closer the r-value is to 1 or -1 the stronger the correlation there is between the two values and the closer the *r*-value is to 0 the less likely there is a correlation between the two values. The equation (1) is shown below where x_i is x samples, y_i is y samples, $\bar{x}$ is mean values of x, and $\bar{y}$ is mean values of y.

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

No set rule tells what an acceptable r-value is to say that there is a strong correlation and the accepted ranges changes based on the industry. Correlation studies can also be misleading as they are only a measure of linearity. A study can show a high r-value and there not be a real correlation. The best example of this can be found in Statistics for Engineers and Scientists by Navidi, W. (2020) it states "For children, vocabulary size is strongly correlated with shoe size. However, learning new words does not cause feet to grow, nor do growing feet cause one's vocabulary to increase".

5.1.2 Linear Regression.
The second test conducted was a linear regression model. This is used to test a hypothesis. For this study, the hypothesis is that as scrap percentage increases so does the number of complaints receive. The test being conducted is at a 95% confidence level. The independent variable for the study is scrap percentage while the dependent variable is customer complaints. To be able to reject the null hypothesis, $p > 0.05$ (the significance level at 95%). This means that changes in the scrap percentage generally do not have any effect on the changes in the number of customer complaints.

5.2 Results
Table 1 shows the results of the correlation study done for the 4 business units.

Table 1. Correlation Study

BU 1			BU 2			BU 3			BU 4		
	Scrap Cost	*Complaints*		*Scrap Cost*	*Complaints*		*Scrap Cost*	*Complaints*		*Scrap Cost*	*Complaints*
Scrap Cost	1		Scrap Cost	1		Scrap Cost	1		Scrap Cost	1	
Complaints	-0.2811	1	Complaints	0.1998	1	Complaints	0.5694	1	Complaints	0.3688	1

As seen from the table above the r-values are relatively low. Generally speaking, to have a strong correlation the r-value should be greater than 0.6. Business unit 1 and 2 show a very weak correlation between scrap cost and complaints, while business unit 3 and 4 show a moderate correlation. Business unit 1 correlation is negative meaning that as complaints go up scrap costs go down. Business units 2,3 and 4 have a positive correlation meaning that as scrap costs increase the complaints increase. Given this data, it can be said that there is no significant correlation between scrap costs and customer complaints. To verify the validity of the correlation, study a regression model was run. The variable that is the most important is the p-value. As stated above if the p-value is greater than the significance level of 0.05 then there is sufficient evidence to reject the null hypothesis. This indicates there is strong evidence that there is likely no correlation between scrap cost and the number of complaints received. Table 2 shows the p-values calculated using the regression model in excel.

Table 2. Linear Regression P-Values

	BU 1	BU 2	BU 3	BU 4
Scrap Cost P-Value	0.0967	0.2427	0.0002894	0.0269

The *P*-Value for business units 1 and 2 is greater than the significance level which gives sufficient evidence to reject the null hypothesis. This also means that there is not sufficient evidence to say that there is a correlation between scrap cost and the number of complaints received. Business units 3 and 4 however are smaller than the significance level meaning there is enough evidence to reject the null hypothesis. This does not mean that we accept the hypothesis. This provides evidence that there is at least some correlation between scrap costs and the number of complaints received. This data lines up perfectly with the correlation study therefore it verifies the validity of both tests.

6. Conclusion

The study showed that there is a potential correlation between scrap costs and the number of complaints received for business units 3 and 4 and that there is likely no correlation for units 1 and 2. However, this data can be misleading, and the study should more than likely be repeated. When pulling together the data the scrap cost was pulled for the entire process, not just the final process. For business units 3 and 4 there are not a lot of sub-processes therefore the total scrap cost is very close to that of the final operation, while business units 1 and 2 have multiple operations that can highly increase the overall scrap and potentially skewing the results seen.

There is also a factor that is not considered and that is the technology being used to evaluate these defects. If the defects are being captured by a 100% vision check or functional test, then the risk of getting to the customer is minimal and therefore can produce a large scrap value without a complaint. Robots and in-process inspection systems equipped with machine vision solutions are used for increased flexibility and quality in automated manufacturing (Oleksandr Semeniuta, Sebastian Dransfeld, Kristian Martinsen, Petter Falkman. 2018). Business unit 1 has 100% critical functional testing for all completed assemblies and a review of the data shows most of the rejects come from this operation and the parts are automatically placed in a scrap bin. This eliminates the risk of shipping a non-conforming part of this type to the customer. These are also fully assembled parts at this point meaning they cost much more than a sub-assembly further skewing the data. Business meanwhile has a 100% visual inspection by experienced inspectors before the parts are packed and shipped.

There is also the factor of human error and technological advancements for monitoring the data. Much of the scrap cost are a manual calculation based on scrap sheets filled out by the production operators and then input into a system that will calculate the cost based on where the part was in the process. This can lead to typos and missing information. Customer complaints are also tabulated manually by using the approved “LOG”. Some customer complaints may not get input. There has also been a large amount of turnover in the departments responsible for inputting all the data which can lead to missing information. If this study were to be completed again taking all these factors into account, then the result may look a lot different.

References

Abbas, S. N., Ahmed, J., Salman, M., &Ashraf, S. R. (2015). Compare Cost of Good Quality & Cost of Poor Quality And Have a Wise Decision: A study from Automobile Industry of Pakistan. IOSR Journal of Business and Management, 17(9), 19-28.

Albliwi, S., Antony, J., Lim, S. A. H., & van der Wiele, T. (2014). Critical failure factors of lean Six Sigma: A systematic literature review. International Journal of Quality and Reliability Management, 31(9), 1012–1030. https://doi.org/10.1108/IJQRM-09-2013-0147

Control Plan Development. Quality. (n.d.). https://quality-one.com/control-plan/.

C. P. Kartha (2004). A comparison of ISO 9000:2000 quality system standards, QS9000, ISO/TS 16949 and Baldrige criteria. TQM Mag., vol. 16, no. 5, pp. 331–340

Cost of Quality (COQ). ASQ. (n.d.). https://asq.org/quality-resources/cost-of-quality.

Cost of Quality. Quality. (n.d.). https://quality-one.com/coq/.

Colledani, M., Tolio, T., Fischer, A., Iung, B., Lanza, G., Schmitt, R., & Váncza, J. (2014). Design and management of manufacturing systems for production quality. CIRP Annals - Manufacturing Technology, 63(2), 773–796.

Daunoriene, A., & Katiliute, E. (2016). The Quality Costs Assessment in the Aspect of Value Added Chain. Quality Innovation Prosperity, 20(2), 119–144.

Dhiravidamani, P. & Ramkumar, A. & S.G., Ponnambalam & Subramanian, Nachiappan. (2017). Implementation of lean manufacturing and lean audit system in an auto parts manufacturing industry – an industrial case study. International Journal of Computer Integrated Manufacturing. 31. 1-16.

Drohomeretski, E., Gouvea Da Costa, S. E., Pinheiro De Lima, E., & Garbuio, P. A. D. R. (2014). Lean, six sigma and lean six sigma: An analysis based on operations strategy. International Journal of Production Research, 52(3), 804–824. https://doi.org/10.1080/00207543.2013.842015

Galli, B. J. (2021). Relationship Between Cost of Poor Quality and Continuous Improvement: Reflection of Literature. International Journal of Applied Logistics (IJAL), 11(2), 55-70.

Garvin, D. A. (1984). Product quality: An important strategic weapon. Business Horizons, 27(3), 40–43. https://doi.org/10.1016/0007-6813(84)90024-7

Gijo, E. V., & Scaria, J. (2014). Process improvement through Six Sigma with Beta correction: A case study of manufacturing company. International Journal of Advanced Manufacturing Technology, 71(1–4), 717–730. https://doi.org/10.1007/s00170-013-5483-y

Hakimi, S., Zahraee, S. M., & Mohd Rohani, J. (2018). Application of Six Sigma DMAIC methodology in plain yogurt production process. International Journal of Lean Six Sigma, 9(4), 562–578. https://doi.org/10.1108/IJLSS-11-2016-0069

Juran, J. M., & A., D. F. J. (2017). Juran's quality handbook: the complete guide to performance excellence. New York: McGraw Hill Education

Mahmood, Shahid; Ahmed, Syed M; Panthi, Kamalesh; Kureshi, Nadeem Ishaque.Built Environment Project and Asset Management; Bingley Vol. 4, Iss. 3, (2014): 296-311.

Misztal, A., Grecu, I., & Belu, N. (2016). Customer satisfaction in the automotive industry. FAIMA Business & Management Journal, 4(1), 44-57.

Mishra, N., & Rane, S. B. (2019). Prediction and improvement of iron casting quality through analytics and Six Sigma approach. International Journal of Lean Six Sigma, 10(1), 189–210.

Montgomery, D. C. (2013). Introduction to statistical quality control. Hoboken, NJ: Wiley.

Navidi, W. (2020). Statistics for engineers and scientists. McGraw-Hill Education. Oleksandr Semeniuta, Sebastian Dransfeld, Kristian Martinsen, Petter Falkman. (2018).Towards increased intelligence and automatic improvement in industrial vision systems. Procedia CIRP, Volume 67, Pages 256-261, ISSN 2212-8271.

Papadimitriou, A., & Westerheijden, D. F. (2010). Adoption of ISO-oriented quality management system in greek universities: Reactions to isomorphic pressures. TQM Journal, 22(3), 229-241.

Pekanov Starcevic, Dubravka & Mijoč, Ivo & Mijoč, Josipa. (2015). QUANTIFICATION OF QUALITY COSTS: IMPACT ON THE QUALITY OF PRODUCTS. Ekonomski pregled. 66. 231-251.

Process FMEA (PFMEA). Quality. (n.d.). https://quality-one.com/pfmea/.

Reeves, C. A., & Bednar, D. A. (1994). Defining Quality: Alternatives and Implications. The Academy of Management Review, 19(3), 419. doi:10.2307/258934

Rust, R. T., Zahorik, A. J., & Keiningham, T. L. (1995). Return on Quality (ROQ): Making Service Quality Financially Accountable. Journal of Marketing, 59(2), 58-70. doi:10.1177/002224299505900205

Saad, N. H., Khalid, Q. M., Halim, N. H. A., & Khusaini, N. S. (2020). A Case Study: Framework of Gap Analysis on Integration of Audit System between IATF 16949 and Toyota Production System. Applied Mechanics and Materials, 899, 219–229.

Saad, N. H., Qhairunisha, M. K., Nurul Hayati, A. H., & Khusaini, N. S. (2020). A case study: Framework of gap analysis on integration of audit system between IATF 16949 and Toyota production system. Applied Mechanics and Materials, 899, 219-229.

Shah, R., and P. T. Ward. 2003. " Lean Manufacturing: Context, Practice Bundles, and Performance." Journal of Operation Management 21 (2): 129 - 149.

Singh, J., & Singh, H. (2020). Application of lean manufacturing in automotive manufacturing unit. International Journal of Lean Six Sigma, 11(1), 171-210.

What Is a Quality Management System (QMS)? ASQ. (n.d.). https://asq.org/quality-resources/quality-management-system.

White, R. E., Pearson, J. N., & Wilson, J. R. (1999). JIT manufacturing: A survey of implementations in small and large U.S. manufacturers. Management Science, 45(1), 1-15.

Biographies

Alexandr M. Sokolov, Ph.D., is a faculty in the Engineering Management Department of the College of Engineering and Computer Science at A-STATE. He holds a B.S., where he focused on Bioinformatics from the University of Tennessee Knoxville, an M.B.A., in Finance from Lincoln Memorial University, and a Ph.D., in Industrial Systems Engineering, Engineering Management from the University of Tennessee Space Institute. Alexandr has over 15 years of infield and teaching experience. His teaching experience includes multiple institutions dealing with Engineering, Management, and Technology disciplines. He is focusing on research dealing with Engineering Management, Performance Management, and Interdisciplinary Studies.

Steven Picklesimon is a student in the Master of Engineering Management Degree Program at Arkansas State University. He holds a B.S in Mechanical Engineering from Wright State University. Steven has over 6 years of quality experience in the automotive and medical industries.

Duaa Nawafleh is a Research Assistant in the Engineering Management Department of the College of Engineering and Computer Science at A-STATE. she holds a B.S in Biomedical Engineering from Jordan University of Science and Technology and a Master of Engineering from Arkansas State University. She worked as a teaching assistant in Jordan University of Science and Technology and Yarmouk University at the biomedical engineering departments there between 2011 and 2019. Also, she worked as a graduate assistant at Arkansas State University in the learning support services as a learning assistant in 2020.

Niamat Ullah Ibne Hossain, PhD is an assistant professor in the Department of Engineering Management at Arkansas State University. Dr. Hossain received his PhD in Industrial and Systems Engineering in 2020 from Mississippi State University (MSU), Starkville, MS. He obtained his Bachelor's degree in Mechanical Engineering in 2010 from Khulna University of Engineering and Technology (KUET) and his MBA in Management Information Systems in 2013 from the University of Dhaka, both in Bangladesh. His main research interests include systems engineering, systems model-based systems engineering/SysML, Systems thinking, Systems resilience, & sustainability management, System dynamics, and systems simulation.